Habitat use by ocelots in south Texas: implications for restoration

Patricia M. Harveson, Michael E. Tewes, Gerald L. Anderson, and Linda L. Laack

Abstract The ocelot (*Leopardus pardalis*) is an endangered cat native to south Texas. Urbanization and agricultural development have resulted in limited and fragmented habitat, making ocelot habitat restoration an important factor in the cat's recovery. We evaluated the use of United States Department of Agriculture-Natural Resource Conservation Service (USDA–NRCS) soil surveys to identify potential restoration sites by examining ocelot habitat use in south Texas from 1982–1990. We analyzed an 8-year data set of ocelot radiotelemetry locations using Geographic Information Systems (GIS) and Bailey's confidence intervals. Ocelots selected habitat with dense (>95%) canopy cover more than open (<75%) canopy cover. Ocelots also selected Camargo, Lardeo, Olmito, and Point Isabel soil series in greater proportion than available. The selected soils also represented 82% of the selected dense canopy cover areas. Our results suggest that USDA–NRCS soil survey maps can be used as a tool for identifying potential areas for ocelot habitat restoration.

Key words canopy cover, GIS, habitat selection, Laguna Atascosa National Wildlife Refuge, *Leopardus pardalis*, ocelot, soil, south Texas, thornshrub

The ocelot (*Leopardus pardalis*) is a federally listed, endangered cat native to south Texas. Habitat loss and fragmentation are the primary causes of its decline (Tewes and Everett 1986, Harwell and Siminski 1990). Tewes and Everett (1986) determined that <1% of the Lower Rio Grande Valley (LRGV) contained optimal ocelot habitat due to loss of native rangeland to agricultural and urban use (Jahrsdoerfer and Leslie 1988). Additional urban and industrial growth is anticipated in the LRGV (Jahrsdoerfer and Leslie 1988); thus, further fragmentation and degradation of remaining habitat patches is likely. Managing land to retain or restore ocelot habitat in south Texas is a conservation goal of the United States Fish and Wildlife Service and the Texas Parks and Wildlife Department (Harwell and Siminski 1990). Consequently, land acquisition and restoration are essential to increase ocelot habitat and sustain or increase current populations.

The relationship of biotic and abiotic habitat variables must be quantified to develop habitat restoration strategies for the ocelot. Previous studies have documented the vegetation composition of ocelot habitats (Shindle and Tewes 1998) and evaluated planting techniques for restoring vegetation (Young and Tewes 1994). The identification of potential restoration sites should include a variety of factors including proximity to ocelot populations, availability of corridors, and restoration potential. While many factors must be considered in determining restoration potential, soil characteristics such as texture, drainage, and fertility influence the success and growth rate of vegetation (Wilde 1946). Although complex, the soil–plant

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relationship is important and should be examined for successful habitat restoration (Wilde 1946, Russell 1973, Jeffrey 1987, Rendig and Taylor 1989). In our study, we used soils to assess the restoration potential of land relative to ocelots. We hypothesized that the indirect selection of soils by ocelots—which is based on habitat characteristics such as canopy coverage, prey abundance, and other variables—could be used to identify lands with potential for restoration into optimal ocelot habitat (e.g., dense thornshrub). Our goal was to evaluate the use of United States Department of Agriculture-Natural Resource Conservation Service (USDA–NRCS) soils data as a tool to identify potential sites for ocelot habitat restoration. The objectives of our study were to determine ocelot use of habitat as classified by canopy cover and soils and to examine the relationship between canopy cover and soils relative to ocelot use.

Study area

Data were collected from 1982–1990 from a study area in northeastern Cameron (378 km^2) and southeastern Willacy (11 km^2) counties, Texas. The primary study site was the 182-km^2 Laguna Atascosa National Wildlife Refuge (LANWR) located 17 km north of Bayview, Texas. The climate was semi-arid and subtropical, with annual precipitation ranging from 38–76 cm. Average daily temperatures ranged from 10°C in January to 36°C in July (Jahrsdoerfer and Leslie 1988). Landscape types included coastal prairies, salt flats, estuaries, and thorn forests. Thorn forests comprised 12 km^2 (6.6%) of LANWR (Laack 1991). Typical vegetation included honey mesquite (*Prosopis glandulosa*), brasil (*Condalia hookeri*), granjeno (*Celtis pallida*), colima (*Zanthoxylum fagara*), Texas ebony (*Ebenopsis ebano*), Texas lantana (*Lantana urticoides*), crucita (*Chromolaena odorata*), Berlandier fiddlewood (*Citharexylum berlandieri*), desert olive (*Forestiera angustifolia*), and alkali sacaton (*Sporobolus airoides*) (Blair 1950, Fleetwood 1973, Williams et al. 1977, Shindle and Tewes 1998). Soils in Cameron County were 90% clay and loam and 3% sandy (Williams et al. 1977). Study-area soils included 9 associations, 32 series, and 50 types. Soil associations included Barrada-Arrada-Lalinda, Harlingen-Benito-Laredo, Laredo-Lomalta-Sejita, Laredo-Olmito-Cameron, Lyford-Lozano-Raymondville, Saucel-Latina-Jarron, Sejita-Lomalta-Barrada, Willacy-Raymondville-Racomes, and Willamar-Latina-Lyford (Williams et al. 1977, Turner 1982, United States Department of Agriculture [USDA] 1994). Topography was flat, with <1% slope and an elevation of 0–10 m (Laack 1991).

Methods

Capture and radiotelemetry

We captured ocelots with wire box traps baited with live chickens from February 1982–December 1990 with the approval of the Texas A&M University-Kingsville Animal Care and Use Committee (no. 1989-5-18). Sedation techniques were described by Beltran and Tewes (1995). We fitted collar-mounted radiotransmitters (Telonics Inc., Mesa, Ariz.) weighing about 125 g around the necks of immobilized ocelots. Ocelots were classified as juvenile (<1 year), sub-adult (1–2 years), and adult (≥2 years) (Tewes 1986, Laack 1991).

We obtained telemetry locations using fixed stations and standard triangulation techniques (Mech 1983) as described by Tewes (1986) and Laack (1991). We occasionally obtained aerial locations when ground locations were not possible. We recorded 10–15 locations/month for each radiocollared ocelot.

Habitat classification

We imported digital thornshrub canopy cover maps (Harveson 1996) and USDA–NRCS soil survey maps for Willacy and Cameron counties into ArcView GIS (Environmental Systems Research Institute, Version 3.3). We classified the study area into 3 thornshrub canopy coverage classifications based on ocular measures. Thornshrub classifications were based on habitat use patterns of ocelots (Navarro 1985, Tewes 1986, Laack 1991, Caso 1994, Shindle 1995). Shindle and Tewes (1998) reported that suitable ocelot habitat was characterized by >97% horizontal canopy cover. We classified study-area canopy cover as dense (>95% horizontal coverage), moderate (75–95% horizontal coverage), or open (<75% horizontal coverage).

We used USDA–NRCS soil survey maps because they are widely available and readily accessible to managers in both paper and digital form. Digital county soil maps were obtained from the Soil Survey Geographic Database (SSURGO, USDA 2002*a,b*). We grouped soils by series to combine soils with similar properties into fewer categories.

Habitat use

Habitat selection can be assessed at various spatial levels (Johnson 1980, Thomas and Taylor 1990, Manly et al. 1993). First- and second-order selection (species range and group range, respectively) allows for inferences on selection in the study area, whereas third-order selection (individual range) limits inferences on selection to an individual's home range. Thomas and Taylor (1990) cautioned that results from third-order selection studies may not hold true at the population level. Johnson (1980) cautioned that habitat use within home ranges could actually be a "higher order of selection" and that such results could be misleading. Thus, we used second-order habitat selection to examine population-level patterns. This analysis was chosen to address the needs of the endangered ocelot population in the LRGV.

We used only adult ocelot locations in our analyses because juvenile location data were dependent on maternal selection of habitat, and sub-adult data included dispersal locations, which would not represent selected habitat. Adult status was assumed 2 years after initial capture of juveniles and 1 year after initial capture of sub-adults (Tewes 1986, Laack 1991). We randomly selected one location/day/adult ocelot from all locations to ensure independence (Swihart and Slade 1985). We overlayed ocelot locations on canopy coverage and soil maps and quantified canopy coverage and soil classifications for each location. We excluded from analysis locations occurring in areas classified as water.

We assessed second-order habitat selection at the population level by pooling all ocelot locations (Johnson 1980, Thomas and Taylor 1990, Manly et al. 1993). We created a 100% minimum convex polygon surrounding all locations using the animal-movement extension in ArcView GIS 3.3 (Hooge and Eichenlaub 2000) to create a collective home range. This collective home range was used as the study-area boundary with the assumption that all portions of the area were equally available to each individual (Manly et al. 1993). We determined ocelot use versus availability of canopy coverage and soil series using 95% Bailey's confidence intervals (Bailey 1980; Cherry 1996, 1998). We use the following terms in our paper: "selected," proportion used was greater than proportion available; "avoided," proportion used was less than proportion available; and "equally used," proportion used was equal to proportion available.

Results

Canopy cover use

The total number of ocelots and ocelot locations used in analyses was reduced from 33 to 27 and 6,806 to 3,031, respectively, after removing juvenile and sub-adult locations and locations occurring in water, and randomly selecting 1 location/day/animal. Canopy coverage availability in the study area was 3% dense, 0% moderate, and 97% open (Figure 1). Ocelots selected dense (>95%) canopy cover and avoided open (<75%) canopy cover (Table 1).

Soil series use

We combined 14 soil classifications with <20 expected locations into the category "other" (Table 2). Ocelots selected 4 series categories (Camargo,

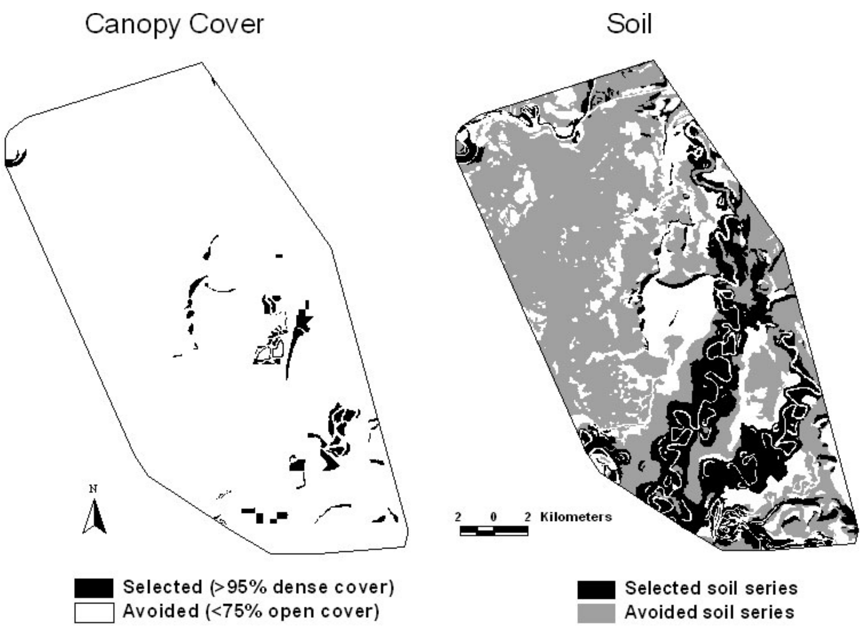

Figure 1. Study-area maps identifying ocelot use of canopy cover and soil series in northeastern Cameron and southeastern Willacy counties, Texas, 1982–1990.

Table 1. Occurrence of ocelots in different canopy cover classifications compared with canopy cover availability in northeastern Cameron and southeastern Willacy counties, Texas, 1982–1990.

Canopy cover[a,b]	Total area (km^2)	Prop. of total area	Number of locations	Expected number of locations	Proportion observed	Bailey's 95% confidence intervals Lower	Upper
Dense (>95%)+	10.957	0.031	1,551	94	0.512	0.491	0.532
Open (<75%)–	343.496	0.969	1,480	2,937	0.488	0.468	0.509
Total	354.453	1.000	3,031	3,031	1.000		

[a] Moderate (75–95%) canopy cover was not present in study area; water was not included in analysis.

[b] + indicates selected (proportion used was greater than proportion available); – indicates avoided (proportion used was less than proportion available).

Laredo, Olmito, and Point Isabel), avoided 11 series categories (Barrada, Benito, Delfina, Harlingen, Latina, Lyford, Raymondville, Sejita, Willacy, Willamar, and Other), and equally used 3 series categories (Chargo, Lomalta, and Tiocano) (Table 2).

Canopy coverage and soil relationships

Soil series composition of open canopy cover (<75% horizontal cover) was similar to the composition of the entire study area, with Willamar series occurring most frequently (20% of both areas, Table 3). Soil composition for dense canopy cover (>95% horizontal cover) differed from open canopy and the study area. Laredo series represented over half (57%) of dense canopy cover soils as opposed to 14% and 12% of the study area and open areas, respectively (Table 3). Willamar series represented only 0.5% of dense canopy cover soils whereas it occurred in 20% of the study area and open canopy soils (Table 3). Ocelots selected 22% and 20% of the soil series found in the study area and open canopy areas, respectively; they selected 82% of the soil series found in dense cover.

Table 2. Occurrence of ocelots on different soil series compared with soil series availability in northeastern Cameron and southeastern Willacy counties, Texas, 1982–1990.

Soil series[a,b]	Total area (km^2)	Prop. of total area	Number of locations	Expected number of locations	Proportion locations	Bailey's 95% confidence intervals Lower	Upper
Barrada–	16.349	0.046	21	140	0.007	0.003	0.013
Benito–	7.309	0.021	13	62	0.004	0.001	0.009
Camargo+	3.687	0.010	103	32	0.034	0.025	0.045
Chargo	9.452	0.027	68	81	0.022	0.015	0.031
Delfina–	3.128	0.009	1	27	0.000	0.000	0.003
Harlingen–	14.820	0.042	75	127	0.025	0.017	0.034
Laredo+	53.260	0.150	1,608	455	0.530	0.503	0.557
Latina–	10.031	0.028	3	86	0.001	0.000	0.004
Lomalta	46.196	0.130	390	395	0.129	0.111	0.148
Lyford–	8.351	0.024	1	71	0.000	0.000	0.003
Olmito+	17.830	0.050	257	152	0.085	0.070	0.101
Point Isabel+	9.592	0.027	332	82	0.110	0.093	0.127
Raymondville–	8.879	0.025	40	76	0.013	0.008	0.020
Sejita–	52.877	0.149	48	452	0.016	0.010	0.024
Tiocano	3.107	0.009	12	27	0.004	0.001	0.009
Willacy–	2.577	0.007	0	22	0.000	0.000	0.002
Willamar–	76.705	0.217	18	656	0.006	0.002	0.011
Other–	10.303	0.029	41	88	0.014	0.008	0.021
Total	354.453	1.000	3,031	3,031	1.000		

[a] Water was not included in analysis; series with <20 expected use values were combined into the category "other" (Borrow Pits, Cameron, Hidalgo, Lalinda, Lozano, Mercedes, Orelia Variant, Porfirio, Racombes, Rio, Rio Grande, Udipsamments, Ustifluvents, and Zalla).

[b] + indicates selected (proportion used was greater than proportion available); – indicates avoided (proportion used was less than proportion available).

Discussion

Although we suggest that specific soil series were selected, we acknowledge that soil selection was indirect and dependent on vegetation canopy coverage. Thus, "soil selection" was relevant only to the extent that plant communities were influenced by soil composition and ocelot use was a function of the habitat characteristics associated with selected soils.

Observational data regarding habitat use by ocelots are well documented; however, few studies have evaluated ocelot habitat selection in the Tamaulipan Biotic Province. Navarro (1985) found most Texas ocelots in dense brush and live-

Table 3. Soil series composition of study area, dense (>95%) canopy cover, and open (<75%) canopy cover in northeastern Cameron and southeastern Willacy counties, Texas, 1982–1990.

Soil series[a]	% of study area	% of dense cover[b]	% of open cover
Barrada	4.2	0.2	4.3
Benito	1.9	tr	1.9
Camargo	0.9	3.8	0.9
Chargo	2.4	3.4	2.4
Delfina	0.8	tr	0.8
Harlingen	3.8	1.5	3.9
Laredo	13.7	57.1	12.4
Latina	2.6	tr	2.7
Lomalta	11.9	6.6	12.0
Lyford	2.1	tr	2.2
Olmito	4.6	6.6	4.5
Point Isabel	2.5	14.3	2.1
Raymondville	2.3	tr	2.4
Sejita	13.6	0.5	14.0
Tiocano	0.8	0.2	0.8
Water	8.8	5.3	9.0
Willacy	0.7	tr	0.7
Willamar	19.7	0.5	20.3
Other	2.7	tr	2.7
Total	100.0	100.0	100.0

[a] Other category includes Borrow Pits, Cameron, Hidalgo, Lalinda, Lozano, Mercedes, Orelia Variant, Porfirio, Racombes, Rio, Rio Grande, Udipsamments, Ustifluvents, and Zalla.

[b] tr = trace (<0.1%).

oak forests. Tewes (1986) reported that 48% of the core areas of 8 adult ocelot home ranges in Texas contained dense brush. In other studies, Laack (1991) and Caso (1994) reported that ocelots used dense thorn forests almost exclusively, and Shindle (1995) provided first-order habitat analysis where dense thornshrub was preferred by 12 of 15 ocelots and avoided by none. These findings were similar to ours, wherein 51% of ocelot locations occurred in dense canopy cover despite its 1% occurrence in the study area. However, use of thornshrub by ocelots in our area was considerably less than the 97% use in northern Mexico reported by Caso (1994), suggesting that the limited availability of thornshrub on LANWR may be forcing ocelots to use less dense, suboptimal habitat.

Conclusions and management implications

Habitat restoration is an important component of ocelot recovery. Optimal habitat in the LRGV is minimal (<1%, Tewes and Everett 1986), and given the expected human population increases and urban expansion projections (Murdock et al. 1997), restoration of habitat will be challenging. Appropriate site selection and restoration strategies are necessary to increase available habitat and restore plant communities capable of supporting an expanding ocelot population in the LRGV. Soil characteristics can provide a reliable framework for the proper selection of restoration methods (Wilde 1946). Our results suggest that ocelots selected certain soils and their associated characteristics (canopy cover, vegetative composition, prey abundance, etc.) and that Camargo, Laredo, Olmito, and Point Isabel soil series should be the focus of habitat restoration based on their potential for supporting optimal ocelot habitat.

Selection of restoration sites should include factors such as proximity to other ocelot habitat and populations, availability of corridors, and restoration potential. Target plant species and ocelot habitat restoration techniques have been identified (Young and Tewes 1994, Shindle and Tewes 1998). Young and Tewes (1994) evaluated techniques for the restoration of ocelot habitat and recommended the use of seedling shelters to accelerate revegetation in the LRGV. Shindle and Tewes (1998) identified shrub species associated with >95% canopy coverage tracts on LANWR. Granjeno, crucita, Berlandier fiddlewood, honey mesquite, and desert olive represented >50% of the species in dense canopy cover areas utilized by ocelots (Shindle and Tewes 1998). They recommended that restoration efforts include the re-establishment of these species to achieve dense canopy cover habitat preferred by ocelots (Shindle and Tewes 1998). We propose that soils can be used to assist in identifying areas most suitable for the re-establishment of these woody plant species. Further, because soils ultimately determine the restoration potential of a site, a detailed understanding of their distribution would reduce the rate of restoration failure in the LRGV.

Soil survey maps (USDA–NRCS) are available in printed and digital (SSURGO) form for all or most counties in the LRGV and are an effective guideline for identifying potential ocelot habitat. Although soil names differ by county, soils with properties similar to those recognized in this study should be identified as potential areas for ocelot habitat restoration. Future research should quantify specific properties of Camargo, Laredo, Olmito, and Point Isabel soil series through field sampling for more detailed criteria in selecting soils for habitat restoration.

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